Rules for the Classification of Stern First Ice Class Ships

July 2021

Lloyd's Register

A guide to the Rules

and published requirements

Rules for the Classification of Stern First Ice Class Ships

Introduction

The Rules are published as a complete set.

Rules updating

The Rules are published periodically and changed through a system of Notices between releases.

July 2021

PLEASE NOTE: No technical changes have been made to this Rule set, only the date has been updated.

■ *Section 1* General

1.1 Scope

1.1.1 These Rules are applicable to ships that are intended to operate in ice going stern first using directional thrust from podded propulsion units or mechanical azimuthing thrusters.

1.1.2 The Rules cross-reference the Ice Class Rules in *Pt 8 Rules for Ice and Cold Operations* of the *Rules and Regulations for the Classification of Ships, July 2021* (hereinafter referred to as the Rules for Ships).

1.1.3 Propulsion is to be provided by podded propulsion units or azimuthing thrusters in accordance with *Pt 5 Main and Auxiliary Machinery* of the Rules for Ships. Other propulsion arrangements will be specially considered.

1.1.4 Consideration of the requirements for low temperature operation (winterisation) is not included in these Rules. *See* the *Rules for the Winterisation of Ships, July 2021*.

1.1.5 The Rules provide a scenario-based framework for consideration of ships operating stern first in ice. Other scenarios for operating in ice, e.g. sideways or oblique angles envisaged for station-keeping and wide channel breaking, will be considered, based on the requirements of *Ch 6 Direct Calculations and Non-Standard Load Scenarios*.

1.1.6 Additional requirements to these Rules may be imposed by the National Authority with which the ship is registered and/or by the Administration within whose territorial jurisdiction it is intended to operate. *See Ch 1, 3.2 National Authority requirements 3.2.1*.

1.2 Classification

1.2.1 Where the requirements given in these Rules are complied with, an appropriate notation may be assigned. *See Ch 1, 3.1 Assignment of ice class*.

1.2.2 Where a notation is desired, the ship is to comply with the requirements of the applicable sections of these Rules, *Pt 8 Rules for Ice and Cold Operations* of the Rules for Ships in addition to the application of the Rules for Ships for open water service.

■ *Section 2* Definitions

2.1 Rule definitions

2.1.1 **Finnish Swedish Ice Class Rules** (hereinafter referred to as FS Rules) are the ice class Rules incorporated into *Pt 8 Rules for Ice and Cold Operations* of the Rules for Ships for first-year ice conditions.

2.1.2 **Polar Class Rules** (hereinafter referred to as PC Rules) are the ice class Rules incorporated into *Pt 8 Rules for Ice and Cold Operations* of the Rules for Ships for multi-year ice conditions.

2.1.3 The definitions in *Ch 1, 2.2 Ship definitions*, *Ch 1, 2.3 Propulsion unit definitions* and *Ch 1, 2.4 Operational definitions* are intended for use in identifying and describing Stern First Ice Class Ships and their operations only.

2.2 Ship definitions

2.2.1 **Conventional Ice Class Ship** is designed to operate in ice-covered waters with the support of an icebreaker or with independent navigation by means of an ice-strengthened bow. The level of capability in ice is dependent on the level of ice-

strengthening, hull form optimisation and propulsive power. Such ships are not covered by these Rules. *See Table 1.2.1 Ship types in relation to ship operations and ice conditions*.

Table 1.2.1 Ship types in relation to ship operations and ice conditions

Ship type	Bow form	Typical ice conditions and operations, *see* Note 1							
		Young Ice		Thin/Medium First-Year Ice		Thick First-Year Ice		Old Ice	
		Bow/Stern First	Navigation	Bow/Stern First	Navigation	Bow/Stern First	Navigation	Bow/Stern First	Navigation
Conventional ice class ship	Open water or ice-strengthened	Bow	Independent	Bow	Unescorted	Bow	Escorted	Bow	Escorted
	Icebreaking	Bow	Independent	Bow	Independent	Bow	Unescorted	Bow	Escorted
Conventional icebreaker, *see* Note 2	Icebreaking	Bow	Independent	Bow	Independent	Bow	Independent	Bow	Independent
Stern First Ice Class Ship	Open water, ice-strengthened	Bow	Independent	Bow or Stern	Independent	Stern	Unescorted	Scenario to be specially determined *See Ch 6 Direct Calculations and Non-Standard Load Scenarios*	
	Icebreaking	Bow	Independent	Bow or Stern	Independent	Bow or Stern	Independent		
Icebreaker, Stern First Ice Class Ship	Icebreaking	Bow	Independent	Bow or Stern	Independent	Bow or Stern	Independent		

Note 1. For definitions of ice conditions, *see Ch 1, 2.6 Ice environment definitions*. The descriptions used in this table are indicative only and are not intended to directly impose restrictions on operation.

Note 2. Conventional icebreakers may act astern during backing and ramming manoeuvres.

2.2.2 **Stern First Ice Class Ship** is equipped with podded propulsion units or azimuthing thrusters and designed for stern first operations in ice, and is expected to operate in ice going stern first as part of its operational profile. Such ships may be provided with a conventional bow for open water or light ice conditions, or for ice an icebreaking bow. *See Table 1.2.1 Ship types in relation to ship operations and ice conditions*.

2.2.3 **Icebreaker** is a sea-going ship especially designed for icebreaking duties. Icebreaker refers to any ship having an operational profile that includes escort or ice management functions, having powering and dimensions that allow it to undertake aggressive operations in ice-covered waters. These Rules may also be applied to icebreakers intended to operate stern first in ice as part of their operational profile. *See Table 1.2.1 Ship types in relation to ship operations and ice conditions*.

2.3 Propulsion unit definitions

2.3.1 In these Rules, propulsion units are considered to be of the pulling type. Other propulsion arrangements, such as nozzles, ducts, push/pull or pushing type applications will receive special consideration based on the philosophy of the Rules and the operational scenarios developed.

2.4 Operational definitions

2.4.1 **Stern**. The end of the ship which incorporates the propulsion unit. This is irrespective of the direction in which the ship transits. *See Figure 1.2.1 Direction-dependent definitions*.

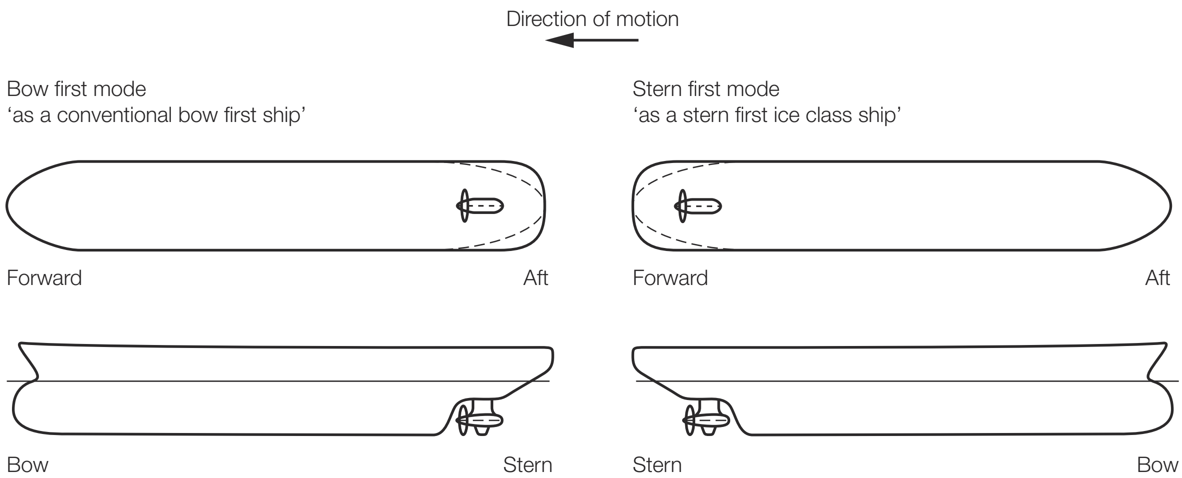


Figure 1.2.1 Direction-dependent definitions

2.4.2 **Bow**. The opposing end of the ship to the stern, as defined in 2.4.1. This is irrespective of the direction in which the ship transits. *See Figure 1.2.1 Direction-dependent definitions*.

2.4.3 **Forward**. The term 'forward' is direction dependent. For the bow first mode 'forward' refers to the bow. For stern first mode 'forward' refers to the stern. *See Figure 1.2.1 Direction-dependent definitions*.

2.4.4 **Aft**. The term 'aft' is direction dependent. For the bow first mode 'aft' refers to the stern. For stern first mode, 'aft' refers to the bow. *See Figure 1.2.1 Direction-dependent definitions*.

2.4.5 **Mode of operation** refers to the direction and method by which the ship operates in ice.

2.4.6 **Bow first mode**. The mode of operation with the bow facing the direction of travel. In the bow first mode the propeller pulls from aft. *See Figure 1.2.1 Direction-dependent definitions*.

2.4.7 **Stern first mode**. The mode of operation with the stern facing the direction of travel. In the stern first mode the propeller pulls from forward. *See Figure 1.2.1 Direction-dependent definitions*.

2.4.8 **Independent**. Navigation in ice which does not adhere to a predetermined route or area and does not require assistance from icebreakers.

2.4.9 **Escorted**. Operation on a predetermined route or area which is supported by icebreakers.

2.4.10 **Unescorted**. Operates on a predetermined route or area which is supported by icebreakers but generally does not require icebreaker assistance.

2.4.11 **Ice transit**. Describes any part of a ship voyage in which ice is encountered at a sufficient concentration or thickness to affect significantly the ship's open water performance.

2.4.12 **Bow first ice transit**. Describes a part of the voyage with the ship going through ice in the bow first mode. The extent (in terms of ice conditions) of a bow first ice transit will be dependent on the ice-strengthening capability incorporated into the bow structure.

2.4.13 **Stern first ice transit**. Describes a part of the voyage when the ship goes through ice in the stern first mode. The extent (in terms of ice conditions) of a stern first ice transit will be dependent on the ice-strengthening capability incorporated into the stern structure.

2.5 Scenario definitions

2.5.1 **Operational scenario** describes, for a way point during operation in ice, the ice conditions that the ship will encounter and the mode of operating.

2.5.2 **Load scenario** is associated with one or more operational scenarios, giving the most critical loading for the hull area or machinery component under consideration as a result of stern first operation in ice.

2.5.3 **Standard load scenario** is the load scenario used as the basis for interpreting the FS Rules and PC Rules for stern first operation in these Rules.

2.5.4 **Non-standard load scenario** is a load scenario that differs from the standard load scenarios in these Rules.

2.6 Ice environment definitions

2.6.1 The World Meteorological Organisation (WMO) definitions for sea ice thickness are given in *Table 1.2.2 WMO definition of ice conditions*.

Table 1.2.2 WMO definition of ice conditions

Development	Ice conditions	Ice thickness
First-year ice	Thick first-year	>1,20 m
	Medium first-year	0,70–1,20 m
	Thin first-year, second stage	0,50–0,70 m
	Thin first-year, first stage	0,30–0,50 m
Young ice	Grey-white	0,15–0,30 m
	Grey	0,10–0,15 m

2.6.2 **Old ice**. Sea ice which has survived at least one summer's melt. May be subdivided into second-year and multi-year ice.

2.6.3 **Ice cover**. The ratio of an area of ice of any concentration to the total area of sea surface within a large geographic location, this location may be global, hemispheric, or prescribed by a specific oceanographic entity such as Baffin Bay or the Barents Sea.

2.6.4 **Level ice**. Sea ice which is unaffected by deformation.

2.6.5 **Brash ice**. Accumulation of floating ice made up of fragments not more than 2 m across, from the wreckage of other forms of ice.

2.6.6 **Ice ridge**. A line or wall of broken ice forced up by pressure. The submerged volume of broken ice in a ridge, forced downwards by pressure, is termed an ice keel. *See Figure 1.2.2 Ice ridge terminology*.

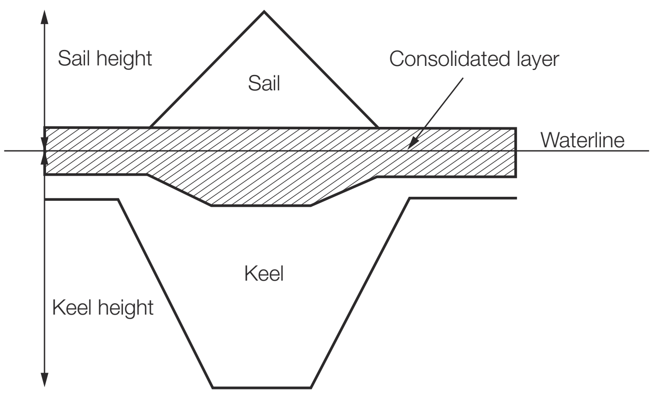


Figure 1.2.2 Ice ridge terminology

2.6.7 **Ice pressure**. Pressure actively causing deformation processes in ice. Pressure may result from ocean, tidal, river or coastal currents, wind or a combination of these.

2.6.8 **Ice channel**. A passage in the ice broken by an icebreaker or a proceeding ship.

2.6.9 **Consolidated (refrozen) ice**. Ice which has melted and/or broken up before reforming under pressure and refreezing.

2.6.10 **Special ice features**. Grounded first-year ridges (stamukhas), massive multi-year ice, etc.

2.6.11 **Open water**. A large area of freely navigable water in which the ice cover is less than 1/10th.

■ *Section 3*
Characters of classification and class notations

3.1 Assignment of ice class

3.1.1 Ships where the relevant requirements of *Pt 8 Rules for Ice and Cold Operations* of the Rules for Ships are complied with in addition to these Rules will be eligible for the ice class notation assigned which is to be supplemented by the additional notation **SFIC**.

3.1.2 For ships where the stern strengthening for operation in ice differs from the requirements for **SFIC**, but where the scenarios include stern first operation, the ice class will be eligible to be supplemented by an additional description indicating the ice-strengthening standard **(<ice class to which the stern is strengthened> Stern First)**.

3.1.3 Where arrangements are proposed that require the ice class to which the stern is strengthened to be higher than the ice class notation assigned (for bow first operation), confirmation of acceptance by the National Authority in the sea area under consideration for operation should be sought.

3.1.4 Ships for which an ice class notation is also assigned in accordance with an alternative recognised Standard or National Authority in the sea area under consideration may be assigned a descriptive note **(<alternative recognised standard to which the stern is strengthened> Stern First)**.

3.2 National Authority requirements

3.2.1 Certain areas of operation may require compliance or demonstration of equivalence with National Authority requirements.

Contents

Chapter 2

Section 1
Standard load scenarios

1.1 General

1.1.1 The requirements in the Rules use standard load scenarios as the basis of interpreting the application of FS Rules and PC Rules to the ship structure, machinery and arrangement. Standard load scenarios are used to indicate the operations identified as resulting in the most critical loading due to stern first operation in ice assumed in these Rules.

1.1.2 Application of the Rules where the intention for stern first operation indicates that alternative load scenarios to those assumed in *Ch 2, 1.2 Hull load scenarios* and *Ch 2, 1.3 Propulsion unit load scenarios* may be more critical will receive special consideration based on load scenarios submitted. *See* Ch *Ch 6, 2 Framework for non-standard load scenarios*.

1.2 Hull load scenarios

1.2.1 The hull standard load scenarios are the operational scenarios considered to give the most critical loading conditions for the stern hull structure of a Stern First Ice Class Ship. Non-standard load scenarios for the hull may be used in determining loads based upon the operational scenarios developed by the designer.

1.2.2 For Stern First Ice Class Ships, the hull standard load scenarios are considered to be a combination case of ridge crossing and turning in ice. The standard load scenarios consider these operations with respect to contact of the hull with the consolidated layer of the ridge and contact of the hull with the consolidated layer of a channel side whilst turning. *See Table 2.1.1 Hull standard load scenario*.

Table 2.1.1 Hull standard load scenario

	Ridge crossing	**Turning in ice**
Prevailing ice condition	Consolidated layer of ridge	Consolidated layer at edge of channel
Stern first mode of operation	Continuous milling/flushing ice	Continuous icebreaking
Ship orientation	Straight on	Turning
Hull areas	Transom and skeg (stern area)	Aft shoulder and ice belt

1.3 Propulsion unit load scenarios

1.3.1 For Stern First Ice Class Ships, the propulsion unit standard load scenarios are considered to be a combination of scenarios associated with the crossing of ice ridges:

(a) Stopped propeller in ridge keel (impact of propeller with ice sufficient to stop propeller rotation) where the propulsion unit body collects ice load from the ridge keel.
(b) Ice sheet consolidated layer crushing at strut.

1.3.2 For the propulsion unit propeller, the standard load scenario is a blade breaking on a thick ice sheet.

1.3.3 The standard load scenario for consideration of the load cases for propulsion unit is given in *Table 2.1.2 Propulsion unit standard load scenario* and shown schematically in *Figure 2.1.1 Propulsion unit standard load scenario*.

Table 2.1.2 Propulsion unit standard load scenario

	Consolidated ridge combination
Prevailing ice condition	Ridge/rubble field
Bow first mode of operation	Not applicable
Stern first mode of operation	Continuous milling/flushing ice
Unit orientation	Unit facing ice, unit at 90° to ice
Criticality	High

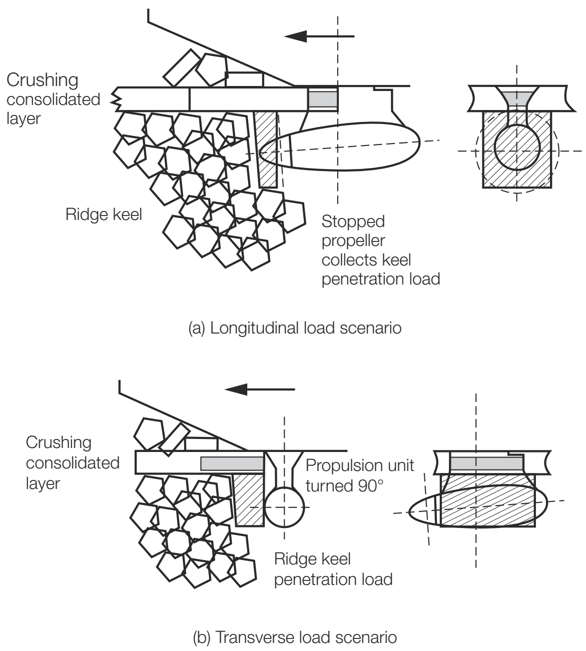


Figure 2.1.1 Propulsion unit standard load scenario

Section 1 General arrangement

1.1 General

1.1.1 This Chapter illustrates the general principles to be adopted for the hull structure of Stern First Ice Class Ships.

1.1.2 The general philosophy of this Chapter is to apply the selected ice class Rules with additional consideration for the hull standard load scenarios in *Ch 2 Operational and Load Scenarios*. The interpretation of this application for the standard scenarios is given in *Ch 3, 2 Application of ice class to hull structures*.

1.2 Rule references

1.2.1 The applicable requirements of the Rules for Ships or Common Structural Rules are to be complied with, taking into consideration *Ch 3, 1.2 Rule references 1.2.2*.

1.2.2 Application of the Rules for the following operational cases:

(a) Design pressure heads based on hydrodynamic and hydrostatic effects are to be applied to the ship as if it were a conventional ship operating bow first.

(b) Rule definitions related to ship hull form (i.e. requirements based on AP and FP locations) are to be considered. For example:

  (i) Distances usually measured from FP of a conventional ship may be required to be measured from the AP when going stern first and are to be taken from the centreline of the propulsion unit strut.

  (ii) Local open water scantlings are to be determined as a conventional bow first ship.

(c) Regulatory aspects such as the International Load Line Convention are to be applied to the ship as if it were a conventional ship operating bow first.

1.2.3 The use of 'forward' and 'aft' in the Rules for Ships (e.g. 'Forward of 0,1*L* of the FP') is to be consistently applied considering the vessel in bow first mode (conventional arrangement) unless otherwise stated. *See Figure 1.2.1 Direction-dependent definitions* in Chapter 1.

1.2.4 When defining the extents of ice-strengthening for ice class Rule requirements, the intersection of the stern stem with the ice load waterline is to be considered the forward perpendicular for ice class Rule reference purposes.

1.3 Interpretations of international conventions

1.3.1 In general, the following approach is to be applied to the interpretation of international conventions:

(a) The use of 'forward' and 'aft' in the Rules for Ships (e.g. 'Forward of 0,1*L* of the FP') is to be consistently applied, considering the vessel in bow first mode (conventional arrangement) unless otherwise stated. *See Figure 1.2.1 Direction-dependent definitions* in Chapter 1.

(b) For navigational related conventions, the use of 'forward' and 'aft' is also to be applied considering the vessel in the stern first mode.

Section 2
Application of ice class to hull structures

2.1 General

2.1.1 The application of bow requirements to the stern for Stern First Ice Class Ships in this Section is intended to substitute the FS Rules and PC Rules requirements for the stern of the ship. Application of other ice class rules to the hull structure may be considered, taking into account the philosophy of this Chapter.

2.1.2 For Stern First Ice Class Ships, the requirements of the bow region of the FS Rules or the bow and bow intermediate areas of the PC Rules are to be applied to the stern, taking into account the stern hull form dimensions, extents and requirements of this Chapter.

2.1.3 The application of ice class Rules to the stern and bow may be different if non-standard scenarios are assumed. As a minimum, the stern is to comply with the requirements of a stern for the assigned ice class. *See Ch 1, 3.1 Assignment of ice class 3.1.4*.

2.1.4 The extent of consideration for the stern hull structure of Stern First Ice Class Ships is from amidships forward in the stern first mode.

2.2 Definitions

2.2.1 **0° WL angle (bow)**. The line that connects points where, in the first instance from the bow, the angle between the waterline and the centreline is zero, commonly termed *forward flat of side*. For application of FS Rules, this corresponds to the border of the part of the side where waterlines are parallel to the centreline nearest to the bow.

2.2.2 **10° WL angle (bow)**. The line that connects points where, in the first instance from the bow, the angle between the waterline and the centreline is ten degrees.

2.2.3 **0° WL angle (stern)**. The line that connects points where, in the first instance from the stern, the angle between the waterline and the centreline is zero, commonly termed *aft flat of side*. For application of FS Rules, this corresponds to the forward border of the part of the side where waterlines are parallel to the centreline nearest to the stern.

2.3 Definition of hull angles for the stern

2.3.1 For application of requirements for PC Rules, the waterline angle, α, at the stern, is to be interpreted using *Figure 3.2.2 Interpretation of waterline angles for Stern First Ice Class Ships*. The waterline length is to be divided into four sub-regions of equal length. The force F, line load Q, pressure P, and load aspect ratio, AR, are to be calculated with respect to the mid-length position of each sub-region. *See Pt 8, Ch 2 Ice Operations - Ice Class* of the Rules for Ships.

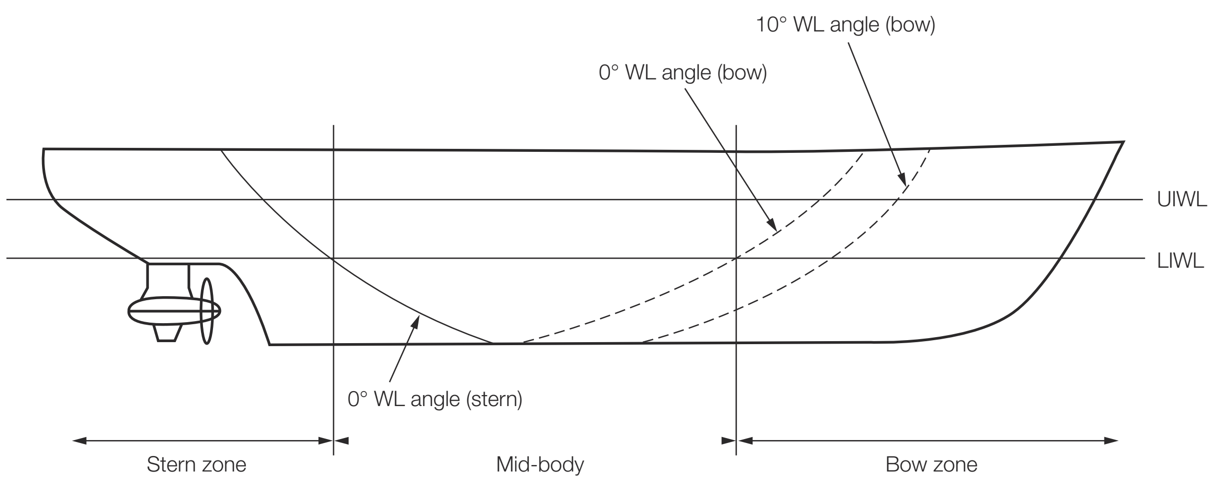
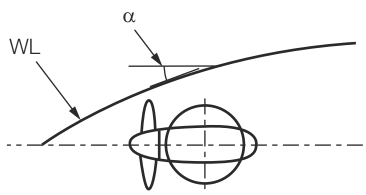
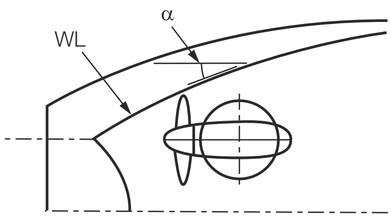


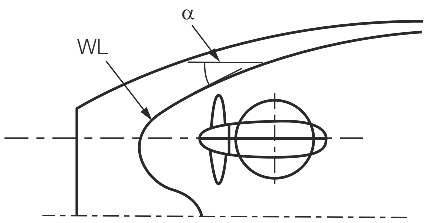
Figure 3.2.1 Definition of waterline angles



(a) single propulsion unit installation



(b) twin propulsion unit installation



(c) twin propulsion unit installation

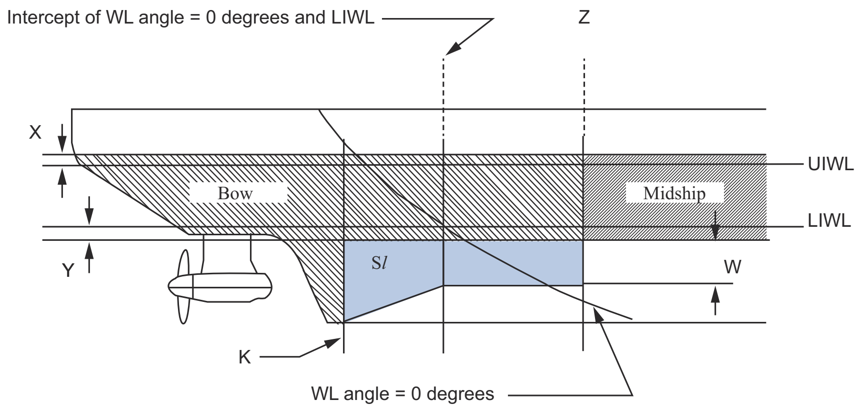
Figure 3.2.2 Interpretation of waterline angles for Stern First Ice Class Ships

2.3.2 For a single propulsion unit installation, the waterline angles are to be interpreted as if the stern centreline were a bow stem. For twin propulsion unit installations, the waterline angles inboard of the centreline of the propulsion unit need not be considered.

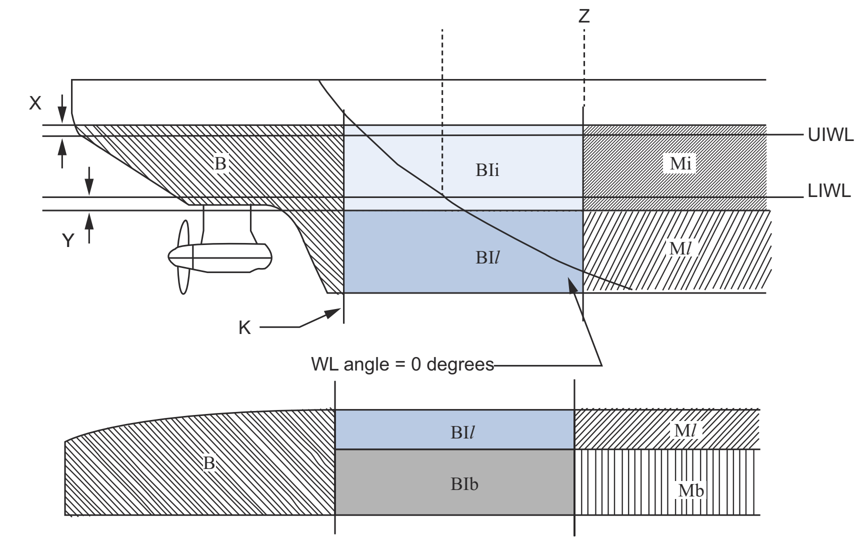
2.3.3 For propulsion unit arrangements not indicated in *Figure 3.2.2 Interpretation of waterline angles for Stern First Ice Class Ships*, the waterline angles are to be specially considered, with respect to the orientation of the structure to the ice load.

2.4 Stern hull areas

2.4.1 Hull strengthening areas are indicated in *Figure 3.2.3 Ice-strengthening extents for stern*.



(a) Stern First Ice Class Ship stern designed to FS Rules



(b) Stern First Ice Class Ship stern designed to PC Rules

B = bow region
BIi = bow intermediate ice belt region
BIl = bow intermediate lower region
BIb = bow intermediate bottom region
Mi = midbody ice belt region
Ml = midbody lower region
Mb = midbody bottom region
Bow = Bow region
Midship = midship region
Sl = lower shoulder region

K = extent of bow region, *see* Note 1.
W = lower extent of lower shoulder region
= 2,5 m below the lower extent of the ice belt, or to a horizontal line from the centre of the propeller shaft line, whichever greater extent

X, Y = upper and lower extents of ice belt, to be taken as:

	X	*Y*
PC1-PC4 inclusive	1,5 m	1,0 m
PC5-PC7 inclusive	1,0 m	1,0 m
1AS FS	0,6 m	0,75 m
1A FS	0,5 m	0,6 m
1B FS	0,4 m	0,5 m

Z = extend of bow intermediate region for PC Rule application or shoulder region for FS Rule application, *see* Note 2.

Note 1. *Ch 3, 2.4 Stern hull areas 2.4.5*

Note 2. *Ch 3, 2.4 Stern hull areas 2.4.7*

Figure 3.2.3 Ice-strengthening extents for stern

2.4.2 If the ship is designed with two sets of UIWL and LIWL for operating forward and stern first in ice, whichever gives the greater requirement is to be considered for hull area definition purposes.

2.4.3 For FS Rule application, the shoulder region is to be divided into two areas. The shoulder ice belt reigon is the area enclosed by the upper extent of the ice belt, *X*, and lower extent of the ice belt, *Y*, and bound longitudinally from *K* to *Z*. The lower shoulder region S*l* is the region bound by the lower extent of the ice belt and a line from the point of intersection of *K* with the baseline to the point of intersection between *W* and a vertical line where the 0° WL line intercepts with the LIWL. *See Figure 3.2.3 Ice-strengthening extents for stern*.

2.4.4 For FS Rule application, the forward and shoulder ice belt regions define the required extent of strengthening for plating. The upper vertical extension of ice strengthening of framing for these ice belt regions is to be taken as 1,0 m above the UIWL. The lower vertical extension of ice strengthening of frames for these ice belt regions is to be taken as 1,6 m below the LIWL. The lower vertical extension of framing for the lower shoulder region need not be greater than the lower extent of the plating.

2.4.5 *K* is the forward extent (considering the ship in the stern first mode) of the bow region for PC Rule application and the extent of forward strengthening required below the ice belt for FS Rule application. For FS Rule application, *K*, is defined as five frame spaces forward of the intersection with the foot of the skeg. For PC Rule application or where no skeg is fitted, *K* may be taken as 0,7*b* aft (considering the ship in the stern first mode) from the centreline of the propulsion unit slewing column, where *b* is the half breadth at UIWL at the centreline of the propulsion unit slewing column.

2.4.6 For FS Rule application, the shoulder ice belt is to be considered a continuation of the forward region. The lower shoulder region, *Sl*, is to have scantlings determined according to midship region requirements.

2.4.7 The aft extent, of the bow intermediate area for PC Rule application or shoulder region for FS Rule application *Z,* is to be located 0,04 *L* aft of the point of intersection between the 0° WL line and the LIWL (with the ship in the stern first mode) or at the point of intersection between the 0° WL line and the lower extent of the ice belt region, whichever gives the greater extent of strengthening.

2.5 Application to Icebreakers

2.5.1 The requirements of *Figure 3.2.3 Ice-strengthening extents for stern*, based on the hull standard load scenarios, may be applied to ships assigned the notation **Icebreaker**. However, additional scenarios may need to be considered due to the specialist operational nature of such ships and the particulars of the hull form.

2.5.2 For icebreakers, it is considered that the consistent application of the philosophy of *Ch 3, 2.4 Stern hull areas*, should be followed alongside the icebreaker's particular operational and load scenarios.

2.5.3 For icebreakers where the intercept of the 0° WL angle (stern) line with the UIWL and LIWL is near coincident, the value of *Z* is to be specially considered but is to be taken as 0,08*L* or 6 m, whichever gives the greater value.

2.5.4 For icebreakers where no parallel mid-body 0° WL angle (stern) exists, the extent of stern strengthening is to be specially considered. In general, the bow intermediate area is to extend aft from *K* by 0,2*L*.

2.6 Additional requirements

2.6.1 For PC Rule application, the bow region is to extend to the bottom shell in way of the propulsion unit(s). For FS Rule application, the forward region is to extend to the bottom shell in way of the propulsion unit(s).

2.6.2 For Stern First Ice Class Ships where different ice classes are used as a strengthening basis for stern first and bow first operating modes, the requirements for the midship region shall be taken from the higher ice class.

2.7 Strength level

2.7.1 For the application of PC Rule requirements, the area factors to be applied to the bow and bow intermediate areas for PC application are given in *Table 3.2.1 PC Rule Area Factors for bow and bow intermediate regions applied to the stern of SFIC ships*.

Table 3.2.1 PC Rule Area Factors for bow and bow intermediate regions applied to the stern of SFIC ships

Ice Class assigned	Bow	Bow Intermediate Ice belt	Bow Intermediate lower	Bow Intermediate bottom
PC1	0,85	0,85	0,65	0,50
PC2	0,85	0,85	0,65	0,45
PC3	0,85	0,80	0,60	0,40

PC4	0,85	0,80	0,55	0,35
PC5	0,85	0,80	0,55	0,30
PC6	0,85	1,00	0,50	0,25
PC7	0,85	1,00	0,50	0,25

2.7.2 For the application of FS Rule requirements, the ice design height to be applied to the bow region is given in *Table 3.2.2 FSICR design height for bow region applied to the stern of SFIC ships*.

Table 3.2.2 FSICR design height for bow region applied to the stern of SFIC ships

Ice Class assigned	h_0	h
1AS FS	0,8	0,30
1A FS	0,6	0,25
1B FS	0,4	0,22
1C FS	0,4	0,22

2.8 Stern stem

2.8.1 Suitable strengthening is required at the stern, where the stern intersects the upper and lower ice waterlines.

2.8.2 The reinforcement of the stern stem is to be plated and well connected to the internal structure.

2.8.3 For single propulsion unit installations, the stern stem is located at the centreline and should be suitably connected to the centreline girder.

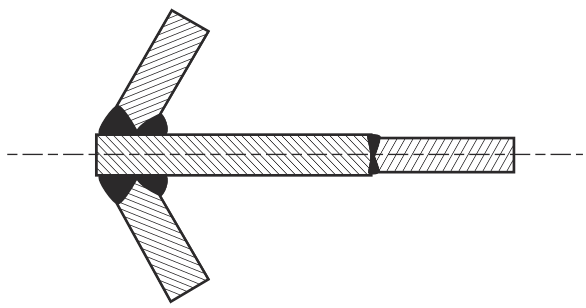


Figure 3.2.4 Example of stern stem arrangement

Contents

Main and Auxiliary Machinery

■ *Section 1* General

1.1 Machinery rule references

1.1.1 This Chapter indicates the requirements to be adopted for the propulsion unit and machinery of Stern First Ice Class Ships. The general philosophy of this Chapter is to apply the relevant sections of *Pt 5 Main and Auxiliary Machinery* of the Rules for Ships to the propulsion unit, with additional ice loads based upon the load scenarios derived in *Ch 2 Operational and Load Scenarios*.

1.1.2 The additional requirements for the machinery arrangement for Stern First Ice Class Ships in this Section are intended to supplement the FS Rules or PC Rules, as applicable.

1.1.3 *Ch 4, 2 Propulsion units* of this Chapter is directly applicable to podded propulsion units and mechanical azimuthing thrusters, as defined in *Pt 5 Main and Auxiliary Machinery* of the Rules for Ships.

■ *Section 2* Propulsion units

2.1 General

2.1.1 Propulsion unit structure scantling requirements are to comply with *Pt 5 Main and Auxiliary Machinery* of the Rules for Ships and the additional requirements below.

2.1.2 The propulsion unit structure and components shall be designed to withstand the loads derived from the standard load scenarios.

2.1.3 A risk assessment is required to be performed for ships operating stern first in ice equipped with single propulsion units to identify components where a single failure could cause loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.2 Propulsion unit structure

2.2.1 The local scantlings of the propulsion unit body and strut are to be derived using the PC Rules using the appropriate area factors in *Table 3.2.1 PC Rule Area Factors for bow and bow intermediate regions applied to the stern of SFIC ships* in Chapter 3 for the propulsion unit location. For FS Rule application, the forward region structural requirements are to be applied using the factors in *Table 3.2.2 FSICR design height for bow region applied to the stern of SFIC ships* in Chapter 3.

2.2.2 Global loads, as required in *Pt 5 Main and Auxiliary Machinery* of the Rules for Ships, are to include longitudinal and transverse forces from ice interaction, in accordance with the standard load scenarios. *See Figure 2.1.1 Propulsion unit standard load scenario* in Chapter 2.

2.2.3 Global loads associated with the standard scenarios are based on the contact area with the keel of an ice ridge that is dependent on the propulsion unit orientation.

2.2.4 The load from the ice ridge is to be considered as two components the force on the propulsion unit strut, F_{C}, and the force collected by the propeller or propulsion unit body, F_{K}. The total moment, M_{TOTAL}, is defined as a combination of F_{C} and F_{K}. *See Table 4.2.1 Global ice loads for propulsion unit*.

Table 4.2.1 Global ice loads for propulsion unit

$M_{TOTAL} = h_c F_C + h_k F_K$ in MNm where the force, F_C, applied to the propulsion unit strut is considered as a crushing failure of the consolidated layer of the ice ridge or side of ice channel: $F_C = p A_C k_1$ in MN and where the force, F_K, collected by the propeller/propulsion unit body is considered as a proportion of the total keel force from the unconsolidated layer of the ice ridge : $F_K = p A_K k_2$ in MN
Symbols
A_C = longitudinal or transverse load area for propulsion unit strut, as defined by load scenario, in m^2 A_K = longitudinal or transverse load area for propulsion unit body, as defined by load scenario, in m^2 h_c = vertical distance from the centre of action of A_C to the lower slewing bearing, in metres h_k = vertical distance from the centre of action of A_K to the lower slewing bearing, in metres p = average ice pressure over the considered load area, MPa k_1 = f (load area, aspect ratio) k_2 = f (ice ridge keel properties: keel depth, internal friction angle, cohesion, effective buoyancy)

2.2.5 Global loads are to be applied to the propulsion unit and strut at the point of assumed action for the dimensioning of primary members.

2.2.6 Determination of the load area A_C and A_K is to be based upon the standard load scenario for the propulsion unit. In general, the height of the load area (contact height) for the strut is recommended to be taken at 0,25 of the design ice thickness h, associated with the ice class. *See Table 4.2.2 Nominal ice thicknesses*. For the application of FS Rules to the above requirements, Ice Class 1A FS and 1AS FS are to be considered as Ice Class PC7 and PC6 respectively. The width of the load area is recommended to follow *Figure 4.2.1 Load areas for propulsion unit global force derivation*.

Table 4.2.2 Nominal ice thicknesses

Ice Class	h
PC1	7
PC2	6
PC3	5
PC4	4
PC5	3

PC6	2,8
PC7	2,5

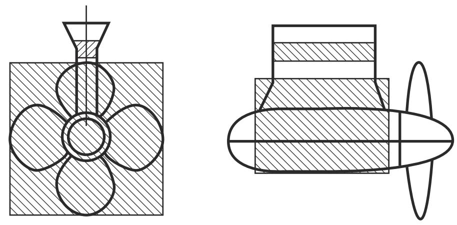


Figure 4.2.1 Load areas for propulsion unit global force derivation

2.2.7 Coefficients k_1 and k_2 are included to acknowledge the varying methods that can be utilised to dimension the global ice loads for the propulsion unit. For the determination of F_C, the pressure-area relationship is also expected to include the load aspect ratio considering the propulsion unit strut geometry. For the determination of F_K, the properties of the ice ridge are to be consistent with expected areas of operation for the ice class notation assigned.

2.2.8 The determination of F_C and F_K will be specially considered for the assignment of SFIC to ships with ice classes PC1, PC2 and PC3.

2.2.9 A pyramid of strength approach is to be adopted for the propulsion unit. The propeller is to be designed to fail before the propeller shafting.

2.2.10 Propulsion unit appendages, such as a pod fin, are to be designed to fail before the propulsion unit support structure.

2.3 Propulsion unit support structure

2.3.1 A Finite Element analysis of the propulsion unit structural integration is to be submitted. *See Ch 6, 1 Stern area structural analysis*.

2.4 Propulsion unit mounting block

2.4.1 The requirements of this Section are to be applied to the propulsion unit mounting block, if applicable.

2.4.2 The stresses in the propulsion unit mounting block are to be verified by direct calculation. *See Ch 6, 1 Stern area structural analysis*.

2.4.3 The loads on the mounting block are to be derived from the maximum bearing reactions from the ice loads applied.

2.5 Load calculations

2.5.1 Calculations employed for the verification of the propulsion unit and support structure are to be in accordance with *Ch 4, 2.2 Propulsion unit structure*, *Pt 5 Main and Auxiliary Machinery* of the Rules for Ships and the requirements of this Section.

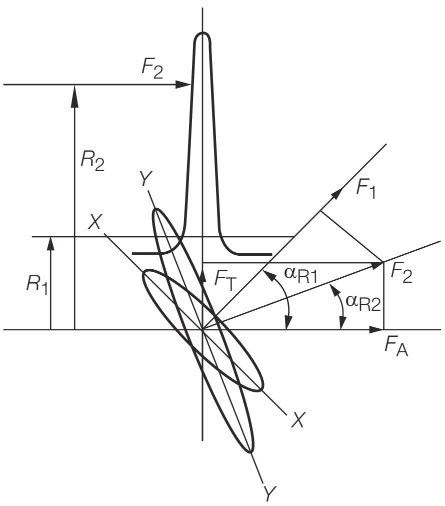
2.5.2 The derivation of the global loads F_x, F_y, and M_x in *Pt 5 Main and Auxiliary Machinery* of the Rules for Ships are to include ice loads based on the propulsion unit operating scenarios. In general, consideration should be given to the following:

(a) Bollard pull;
(b) Longitudinal ice load, Fl_L;
(c) Transverse ice load, Fl_T;
(d) Breaking force on one blade Fl_P;
(e) Propeller open water thrust;
(f) Self weight.

2.5.3 For the propulsion unit structural integration and support structure, the longitudinal ice load (Fl_L) and transverse ice load (Fl_T) are to be applied at their resultant point on the propulsion unit strut. These may be determined by the summation of ice ridge forces F_C and F_K in *Table 4.2.1 Global ice loads for propulsion unit* or from the blade break force Fl_p, whichever is the greater.

2.5.4 For initial dimensioning purposes, the breaking force on one blade Fl_p, at a radius of 0,8R, is to be taken as F_T or F_A, whichever is the greater, may be considered as an alternative to the relevant blade break load cases of the PC Rules and FS Rules. *See Table 4.2.3 Bearing axial and tangential ice loads using simplified blade break force for initial dimensioning*.

Table 4.2.3 Bearing axial and tangential ice loads using simplified blade break force for initial dimensioning

Tangential ice load	$F_T = F_2 \sin \alpha_{R2}$ kN
Axial ice load	$F_A = F_2 \cos \alpha_{R2}$ kN
Symbols	
$F_1 = 0{,}1\, \sigma_M \dfrac{c_r\, t_r^2}{R_2 - R_1}$ kN	
$F_2 = \dfrac{F_1}{\cos(\alpha_{R1} - \alpha_{R2})}$ kN	
where R_1 = radius at root section, in mm R_2 = $\left[\frac{2}{3}\left(R - R_1\right)\right] + R_1$ mm R = propeller radius, in mm $c_r\, t_r^2$ = actual value of blade section (chord length and thickness) at R_1 cm^3 σ_M = minimum specified tensile strength of propeller material, in N/mm^2 α_{R1}, α_{R2} = *see* Figure below	
 where Section X-X is the propeller section at R_1 Section Y-Y is the propeller section at 0,8R	

2.5.5 Propulsion unit structure global ice loads are to be used for the dimensioning of primary members of the propulsion unit and strut.

2.6 Propulsion shafting

2.6.1 The bearing reactions on the propulsion shaft are to be based on the following load cases:

(a) Bollard pull;
(b) Breaking force on one blade (axial and tangential components);
(c) Propeller load components for open water operation;
(d) Propulsion unit self weight.

2.6.2 The bearing life calculations are to include an assumed proportion of time in ice, according to the ship's intended operational profile.

2.6.3 The axial (F_A) and tangential (F_T) ice loads associated with blade break load, used for calculating bearing reaction forces on the propulsion shaft for initial dimensioning purposes, may be in accordance with *Table 4.2.3 Bearing axial and tangential ice loads using simplified blade break force for initial dimensioning*. Dynamic analysis utilising the relevant load cases of the PC and FS Rules is required for deriving the final design reaction forces.

2.6.4 Reactions for the radial bearings supporting the propeller shaft line are to be calculated using the following forces:

(a) Propeller open water thrust and ice impacts (dynamic case).
(b) Ice loads F_A and F_T from *Ch 4, 2.6 Propulsion shafting 2.6.3* (static case).

2.6.5 The bearing dimensions are to be determined for the following load cases:

(a) Dynamic (for lifetime loads).
(b) Static.

2.6.6 The dimensioning for cases *Ch 4, 2.6 Propulsion shafting 2.6.5* and *Ch 4, 2.6 Propulsion shafting 2.6.5.(b)* in 2.6.5 should be in accordance with the bearing manufacturer's or other recognised method.

2.6.7 Axial loads at the thrust bearing are to be calculated from the following:

(a) Bollard pull and ice torque contribution from rotating propellers (dynamic), F_D

$$F_D = 1,1T_B + \frac{1}{N}\left(\frac{Q_I}{0,9R}\right) \pm \left(\frac{N-1}{N}\right)\left(\frac{Q_I}{0,9R}\right) \text{kN}$$

(b) Axial ice load (static), if required for initial dimensioning purposes F_A
(c) Axial ice load derived from the PC Rules or FS Rules load case, whichever is applicable

where

T_B = bollard pull, in kN
N = number of blades
Q_I = maximum ice torque
= $m(2R)^2$
R = propeller radius
m = as defined in *Table 4.2.4 Determination of factor, in metres*
F_A = as defined in *Ch 4, 2.6 Propulsion shafting 2.6.3*.

Table 4.2.4 Determination of factor, in metres

Ice Class	*m*
PC7	15,7
PC6	21,1
PC5	24,2
PC4	29,1
PC3	30,0
PC2	31,0
PC1	33,0

2.6.8 Requirements for the dimensioning of propulsion shafting are to be in accordance with the pyramid of strength philosophy applicable to both FS Rules and PC Rules application.

2.6.9 Shaft coupling bolts are to be dimensioned to account for the following in combination:

(a) Pre-stress due to tightening torque.
(b) External loads due to bolt array bending moment and blade break ice load, per bolt. Coupling bolts are to be dimensioned so that the maximum stress, σ_B derived from F_B does not exceed the bolt yield strength σ_{YB} by a safety factor of 1.2:

$$\frac{\sigma_{YB}}{\sigma_Y} \geq 1,2$$

where

σ_B = F_B/A_a

F_B = $F_{PRE} + \frac{K_1}{K_1 + K_2}\left(F_E + \frac{F_A}{N}\right)$

A_a = cross sectional area of bolt in mm^2

F_{PRE} = pre-stress due to tightening torque

K_1 = bolt elastic constant

K_2 = foundation elastic constant

n = number of bolts in flange

F_E = maximum load due to bending moment, in kN

F_A = as defined in *Ch 4, 2.6 Propulsion shafting 2.6.3*.

2.7 Propeller

2.7.1 The strength of propellers are to be verified using the PC Rules or FS Rules, as applicable.

2.7.2 Alternative methods for assessing the propeller strength to those prescribed by ice class rules will be considered. The formulations for pushing type propellers in the PC Rules may be used as guidance in determining the strength requirements for pulling propellers of Stern First Ice Class ships.

2.7.3 The propeller loading in *Ch 4, 2.7 Propeller 2.7.1* should take into account the propulsion unit load scenarios derived in *Ch 2, 1 Standard load scenarios*, where applicable.

2.7.4 In general, the following cases are to be considered when determining loads in *Ch 4, 2.7 Propeller 2.7.2*:

(a) Propeller blade contact and non-contact loads during ice milling;
(b) Propeller stopped in ice condition.

2.8 Propeller bolts

2.8.1 Propeller fixing bolts are to be designed with a factor of safety of 1,5.

2.8.2 The loading for propeller bolts should consider the following:

(a) Pre-stretch loads;
(b) Centrifugal loads;
(c) Ice loads.

2.8.3 The ice loads in *Ch 4, 2.8 Propeller bolts 2.8.2.(c)* are to be derived from the torque to break the blade root due to an ice strike.

2.9 Steering system

2.9.1 The slewing ring bearing reactions are to be calculated from the load cases in *Ch 4, 2.5 Load calculations 2.5.2*. The factor of safety is to be taken from *Pt 5, Ch 9 Podded Propulsion Units* of the Rules for Ships.

2.10 Propulsion unit power

2.10.1 For Stern First Ice Class Ships, ice model tests are to be used to verify ice performance with propulsion unit power if minimum power is a requirement of the assigned ice class.

■ *Section 3* **Machinery arrangement**

3.1 General

3.1.1 The positioning and structure of sea inlets and connections are to be specially considered with regard to the ingress and impact of ice during stern first mode.

3.1.2 Provision is also to be made for access to the sea chest to enable freeing of ice by both mechanical and steam hose. *See* the *Rules for the Winterisation of Ships, July 2021* and *IMO Guidelines on Design and Construction of Sea Inlets under Slush Ice Conditions MSC/Circular.504 – Guidance on Design and Construction of Sea Inlets Under Slush Ice Conditions – (28 April 1989)*.

3.1.3 De-icing of ballast tank suctions may need to be considered, depending on the anticipated operational profile.

3.1.4 The emergency fire pump is to be arranged to allow ice-free suction in both bow first and stern first modes.

Contents

■ *Section 1* Navigation equipment

1.1 Bridge layout

1.1.1 A stern facing bridge is required for any ship intending to operate stern first in ice for extended periods of operation. A stern facing bridge is defined as a bridge giving a clear view over the stern from the main steering position.

1.1.2 Workstations are to be provided that permit both bow first and stern first navigation. Alternatively, one workstation may be arranged with access to those controls and instrumentation necessary, relevant to controlling the ship's course for both bow first and stern first operation.

1.1.3 The workstations described in *Ch 5, 1.1 Bridge layout 1.1.2* are to be equipped with all instrumentation and controls necessary for navigation of the ship, as listed in *Pt 7, Ch 9 Navigational Arrangements and Integrated Bridge Systems* of the Rules for Ships.

1.1.4 The positioning of funnels is, as far as is practicable, not to obscure the view from the stern facing work station, or the main steering position when operating stern first.

1.1.5 The combination of bridge wings and forward facing and stern facing workstations should enable a suitably complete view around the ship for bow first and stern first navigation.

1.2 Changeover of control

1.2.1 Where multiple workstations are provided, provision is to be made to indicate which workstation is in control.

1.2.2 Clear indication is to be given to show which bridge systems are in control for bow and stern first operation.

1.3 Navigation lights

1.3.1 Two sets of navigation lights are to be fitted for bow first and stern first navigation.

1.4 Searchlights

1.4.1 Searchlights are to be provided to enable effective independent navigation in ice at night. The searchlights provided should be available for bow first and stern first operation.

1.5 Radars

1.5.1 For stern first mode, forward facing radars are to be provided or radars with no shadow zone.

Contents

Chapter 6

■ *Section 1* Stern area structural analysis

1.1 General

1.1.1 A structural analysis is to be provided for the stern area of the ship. The purpose of the structural analysis is to validate the integration between the stern and the propulsion unit with the global ice load forces determined for the propulsion unit when going stern first.

1.2 Model extent

1.2.1 The structural analysis model is to extend from the extreme stern to the first bulkhead aft of the propulsion unit in the stern first mode.

1.2.2 The model may be of half breadth, provided arrangements are symmetrical about the centreline.

1.2.3 Openings are to be considered.

1.3 Assessment

1.3.1 The axial and tangential global loads as derived in *Ch 4 Main and Auxiliary Machinery* are to be applied to the model as separate and combined longitudinal and transverse load cases.

1.3.2 The propeller blade break load at 0,8R as derived from *Table 4.2.3 Bearing axial and tangential ice loads using simplified blade break force for initial dimensioning* in Chapter 4 is to be applied as a load case considering the breaking load in its worst (lowest) position.

1.3.3 Load cases, including accounting for the propulsion unit self weight and hydrostatic loads, may be required, based upon the actual aft end arrangement and geometry. *See also Pt 5, Ch 9, 4.3 Direct calculations* of the Rules for Ships.

1.3.4 Maximum combined stresses and buckling strength are to be assessed. The limiting design stress criteria are to be taken from *Pt 5, Ch 9, 4.2 Hull support structure 4.2.6* of the Rules for Ships.

■ *Section 2* Framework for non-standard load scenarios

2.1 General

2.1.1 This Section provides a framework for the determination and application of non-standard load scenarios to ships operating in ice using directional thrust propulsion units, where the operation of the ship/unit differs from that usually assumed from the standard loads scenarios for a Stern First Ice Class Ship indicated in *Ch 2 Operational and Load Scenarios*.

2.1.2 Non-standard load scenarios may include:

(a) Oblique and sideways ice breaking;
(b) Dynamic positioning in ice.

2.1.3 The requirements of this Section are not applicable if the standard scenarios are applied.

2.2 Defining operational scenarios

2.2.1 All modes of operation and ice conditions in which the ship is expected to operate are to be identified.

2.2.2 The combination of modes and ice conditions (operational scenarios) forms the operational envelope.

2.2.3 Standard scenarios may be used as a basis and supplemented by scenarios specific to the ship's operation.

2.2.4 Operational scenarios shall, as a minimum, define:

(a) General mode of operation for the ship;
(b) Ice conditions expected in this mode;
(c) Evaluation of specific hull and machinery areas loaded.

2.2.5 Operational scenarios are to be made available to LR where they form the basis of the non-standard load scenario definition.

2.3 Evaluating operational scenarios

2.3.1 Operational scenarios are to be evaluated by the Operator and designer in terms of frequency and consequence. This constitutes the risk level for each scenario.

2.3.2 Appropriate definitions of frequency and consequence are to be agreed between the designer and Operator.

2.3.3 Operational scenarios are to be ranked in terms of criticality as a combined product scoring of frequency and consequence.

2.3.4 A level of acceptable criticality is to be proposed.

2.3.5 Operational scenarios associated with the highest critical scoring are termed Critical Scenarios.

2.4 Mitigation of critical scenarios

2.4.1 Critical scenarios require mitigation methods to be proposed in order to reduce the frequency or consequence to an acceptable level.

2.4.2 Mitigation methods for each critical scenario are to be developed. Methods of mitigation may include, but are not limited to:

(a) Reappraisal of the scenario from an operational perspective;
(b) Use of basis ship data;
(c) Use of damage record analysis for ice load determination;
(d) Use of established theoretical methods for ice load determination;
(e) Use of ice class Rule requirements above Rule minimum levels.

2.5 Review of critical scenarios

2.5.1 Critical scenarios and associated mitigation methods are to be reviewed by the Operator and designer. If the critical scenarios and mitigation methods form the basis of non-standard load scenarios, they are to be submitted to LR for review.

2.5.2 The review will involve a reassessment of the criticality scoring of the scenarios, in conjunction with the mitigation methods, using the philosophy of *Ch 3 Ship Structures* and *Ch 4 Main and Auxiliary Machinery* of these Rules.

2.5.3 Agreed mitigation methods are to form the basis of the load scenarios for application, using the philosophy of the requirements in these Rules and are to be documented as indicated in *Ch 6, 3 Scenario document for non standard load scenarios*.

■ *Section 3*
Scenario document for non standard load scenarios

3.1 General

3.1.1 The scenario document, which is design specific, is required for applications where operational scenarios do not match the standard load scenarios in *Ch 2, 1 Standard load scenarios* and is to include details of the scenarios selected for deriving and applying ice loads.

3.1.2 The scenario document is to address the philosophies in the Rules and provide justification for deviation from the requirements in *Ch 2 Operational and Load Scenarios*.

3.2 Scenario document contents

3.2.1 This Section is applicable to the consideration of non-standard scenarios and for validation of the propulsion unit loading for the assignment of SFIC to ships with the ice class notations **PC1**, **PC2** or **PC3**.

3.2.2 The following should be contained within the submitted document:

(a) Details of ice conditions assumed;
(b) Operational scenarios for hull and propulsion unit;
(c) Criticality matrix for hull and propulsion unit scenarios;
(d) Supporting load and operational data for the criticality matrix;
(e) Description of propulsion unit and/or hull loading areas with reasons for selection;
(f) Proposed strengthening standards for each load area;
(g) Arrangement of propulsion devices;
(h) Derived load data based full scale measurement or other predictive means;
(i) Details and justification from the Rule philosophy.

3.2.3 The above document is intended to enable LR to assess the suitability of the proposed hull and propulsion unit strengthening for the assumed operational profile of a Stern First Ice Class Ship.

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